Lead accumulation in Siam weed (*Chromolaena odorata*), Node weed (*Synedrella nodiflora*) and Water leaf (*Talinum triangulare*): Potential phytoremediators

Aiyesanmi, A.F; Okoronkwo, A.E and Sunday O.M.

Department of Chemistry, School of Sciences, The Federal University of Technology, Akure, Nigeria

**ABSTRACT**

The plant species used in this experiment *Chromolaena odorata*, *Synedrella nodiflora* and *Talinum triangulare* were selected on the basis of their widespread distribution in Nigeria. The ability of these plants to tolerate and accumulate Pb was investigated. Also, the effect of Ethylene diaminetetraacetic acid (EDTA) on the phytoremediating potential of the plants was monitored. The uptake of Pb in these plants was in the order: *S. nodiflora* $\rightarrow$ *C. odorata* $\rightarrow$ *T. triangulare* with a corresponding bioaccumulation factor (BF) of $0.28\pm0.08$ - $0.50\pm0.14$, $0.20\pm0.05$ - $0.39\pm0.16$ and $0.17\pm0.03$ - $0.27\pm0.09$ respectively. Addition of EDTA significantly increased the uptake of Pb in these plants with a consequent increase in the BF of $0.33\pm0.02$ – $0.61\pm0.09$, $0.28\pm0.09$ – $0.43\pm0.19$ and $0.22\pm0.04$ – $0.28\pm0.13$ in the order above. This order of Pb uptake was the same for untreated and EDTA-treated contaminated soil. However, the transfer factor (TF) was in the order *T. triangulare* $\rightarrow$ *C. odorata* $\rightarrow$ *S. nodiflora*. Also, *S. nodiflora* gave the highest root and shoot biomass production which confers on it an additional advantage for the purpose of phytoremediation. *S. nodiflora* possess the ability to be useful for the purpose of Phytoremediation of Pb contaminated soil.

**Keywords:** Phytoremediation, Ethylene diaminetetraacetate (EDTA), Soil, heavy metal, contamination.

**INTRODUCTION**

Phytoremediation is an emerging technology that employs the use of plants for the removal of heavy metals from contaminated soil [1]. However, contamination has resulted from industrial activities such as mining and smelting of metalliferous ores, electroplating, gas exhaust, energy and fuel production, fertilizer and pesticide application and generation of municipal waste [2].
The threat posed by heavy metals to human and animal health is aggravated by their long-term persistence in the environment. For instance, Pb one of the more persistent metals, was estimated to have a soil retention time of 150–5000 years [3]. Phytoremediation has been put forward since the late 1980’s to remove heavy metals from contaminated soil by harvesting the plants without damaging the soil. It has attracted much attention because it is environmentally friendly and relatively cheap [4, 5]. Some plants termed as phytoremediators are capable of absorbing large amounts of heavy metals from the soil and accumulating these metals in their tissues [6, 7]. Up to date, over 400 different hyperaccumulating plant species have been identified [8].

One of the greatest concerns for human health is caused by Pb contamination [1]. Lead (Pb) is a major anthropogenic pollutant and has accumulated in different terrestrial and aquatic ecosystems [9]. Pb has limited solubility in soil and is generally not available for plant uptake due to complexation with organic matter, sorption on oxides and clays or precipitation as carbonates, hydroxides and phosphates [10]. Hence the two major limitations to Pb phytoremediation are: low bioavailability in soil and poor translocation from root to shoot [11]. One way to induce Pb solubility is to decrease soil pH [12]. To enhance metal solubility, plants are believed to excrete organic ligands [13] or lower the soil pH in the rhizosphere [14].

The use of synthetic chelates has been shown to dramatically stimulate the potential for Pb accumulation in plants. These compounds such as EDTA, DTPA(Diethylene triamine pentaacetate) and low molecular weight organic acid such as oxalic acid and citric acid, prevent Pb precipitation and keep the metals as soluble chelate-Pb complexes available for uptake into roots and transport within plants[1]. Ethylene diaminetetraacetate (EDTA) is probably the chelating agent that is most efficient at increasing the solubility of heavy metals in soil solutions from the solid phase [15-18]. EDTA application solubilizes about 80% of the total soil metal thereby making them available for phytoextraction [19].

In furtherance to the ongoing investigation in the field of phytoremediation, Talinum triangulare, Chromolaena odorata and Synedrella nodiflora had been used in this study to evaluate their tolerance and accumulation ability to lead. Also, the effect of EDTA on the phytoremediating potential of these plants had been investigated. The choice of these plants is based on their widespread availability and demonstration of tolerance to conditions not favourable for the growth of other plants in Nigeria. Also, these plant species have the ability to co-exist on the same field. This feature prompted their simultaneous study under similar experimental conditions. This research work was carried out at the Chemistry Department of The Federal University of Technology, Akure, Nigeria.

**MATERIALS AND METHODS**

2.1 Soil sampling and characterization

Soil used in this experiment was obtained from a Pb-uncontaminated area within the territory of The Federal University of Technology, Akure, Nigeria. All reagents used were of analytical grade (BDH Laboratory supplies, Poole, England) The soil pH was determined in a mixture of soil and deionized water (1:2, w/v) with a glass electrode [20]. Total organic carbon content was determined using the Walkley-Black wet oxidation approach [21]. Total Nitrogen was determined using the Kjeldhal method [22]. Cation exchange capacity (CEC) and amounts of exchangeable Ca and Mg were determined using the ammonium acetate method [23]. Total phosphorus was
determined colourimetrically. Total background lead concentration was determined using Atomic Absorbtion Spectrophotometer (Buck scientific, 210 VGP) after the soil sample (1g) was weighed and digested with a mixture of concentrated HF and aqua-regia. Soil particle size was determined using the hydrometer method.

2.2 Pot experiments
2kg of air dried soil was weighed and transferred into plastic pots and watered with deionized water. Seedlings of these plants were transplanted from the Pb-uncontaminated site into the pots and allowed to stabilize for about one week. The soil had been treated with NPK fertilizers to enhance the growth of the plants. After 1 week when the plant samples had stabilized, the pots were weeded and thinned to one plant per pot for contamination. The pots with the plant samples were placed in a screenhouse where they are exposed to approximately 12 hours of daylight. 125 pots per plant species were monitored over a period of 4 weeks.

2.3 Lead contamination and amendment treatment
Each plant specie had five controls. Different concentrations of 50, 100, 200, 500 and 1000ppm of Pb [from Pb(NO$_3$)$_2$] were prepared. 150ml of 50ppm lead concentrations was added to 24 pots. This was then repeated for the other lead concentrations to make a total of 120 contaminated pots. EDTA concentrations of 50, 100, 200, 500 and 1000ppm were also prepared. 60 out of the already contaminated pots were treated with 75ml of corresponding EDTA solutions (Pb: EDTA; 1:1). This procedure was repeated for the other plant samples.

2.4 Plant harvest and analysis
Plants on contaminated soil treated with EDTA and those not treated with EDTA were harvested in triplicates on a weekly basis. The plant shoot cut at the soil surface were harvested, the roots were washed in tap water until free of soil particles. The shoots and roots are then washed with deionized water, oven dried at 80$^0$C for 24 hours, weighed and then ground into powder using pestle and mortar.

0.5g of dried plant sample was weighed and digested overnight in 69% HNO$_3$ and 30% H$_2$O$_2$ (vlv : 10ml) and later heated at 120$^0$C for 2 hours[24]. The digested solutions were filtered using whatman no 1 filter paper and diluted to 50ml with deionized water. The concentrations of Lead in the digested solutions were determined using Atomis Absorbtion Spectrophotometer (Buck scientific, 210 VGP).

2.5 Statistical analysis
Each set-up was done in triplicates to ensure reproducibility and minimize error. Data were expressed as means with standard deviation and were subjected to two-way ANOVA with soil treatments and plant species as independent factors. The Least Significant Difference (LSD) multiple range test ($P \leq 0.05$) was used to evaluate differences between means of treatments and plant species.

RESULTS AND DISCUSSION

3.1 Soil physicochemical properties
The results obtained from the soil analysis are as shown in table 1. The study soil had a pH of 5.96 which is weakly acidic and will not favour bioavailability of Pb in soil solution. According
to McBride [12], one way of increasing the Pb solubility in the soil is to reduce soil pH. Hence, the addition of EDTA as an enhancing agent to improve the bioavailability of the metal in the soil. Furthermore, the soil particle size recorded was 53.52% sand, 32.48% clay and 14% silt. The classification on the textural triangle is sandy-clay-loam. This relatively high percent of clay could encourage sorption of Pb thereby reducing its solubility and bioavailability in the soil [1]. The organic matter content, level of N and P were relatively low which shows that the soil is deficient of nutrient. For the purpose of phytoremediation, a plant with a healthy growth and good biomass yield is desired, hence, the need for addition of NPK fertilizer. The soil background Pb concentration was 53.57 mg/kg.

Table 1: Soil characterization

<table>
<thead>
<tr>
<th>pH</th>
<th>Texture (%)</th>
<th>OM(%)</th>
<th>CEC (cmol/kg)</th>
<th>N(%)</th>
<th>P (%)</th>
<th>Pb (mg/kg)</th>
<th>Ca/Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.96</td>
<td>53.52</td>
<td>32.48</td>
<td>14.00</td>
<td>2.05</td>
<td>13.14</td>
<td>0.378</td>
<td>0.07</td>
</tr>
</tbody>
</table>

OM: Organic matter, CEC: Cation exchange capacity

Fig 1a: Plot of dry weight of shoots against Weeks after Planting (WAP)

3.2 Effect of contamination on plant growth

At harvest, *T. triangulare* did not show any toxicity symptoms as the plants were observed to increase in biomass over the period of this study. Figures 1a and b shows the plot of dry weight of plants on 1000 ppm contaminated soil against weeks. It could be seen that these graphs gave a positive slope indicating a direct relationship between dry weight and duration of study (in weeks). Similarly, *C. odorata* did not show any symptoms of toxicity during the period of this study indicating the low concentration of Pb in this plant. This is in agreement with the report of Nie et al [25] that Lead with low concentration could accelerate the growth of *C. odorata*. For *S. nodiflora*, contaminants do not have any effect on the plants in the first three weeks after contamination. However, in the fourth week, yellowing of the plant leaves were observed in those contaminated with 1000 ppm of Pb treated with EDTA which coincidently gave the highest absorption of Pb. This yellowing indicates the phytotoxicity of the EDTA-metal complex.
Of the three plant species, *T. triangulare* gave the smallest biomass (both root and shoot), followed by *C. odorata*. The highest root and shoot biomass was observed in *S. nodiflora*. In view of this biomass production, *S. nodiflora* may be the preferred choice since the target of phytoremediation is to harvest the overground parts of the plants which is expected to be rich in the concentration of the heavy metal of interest.

**3.3 Uptake of lead into plant parts**

**3.3.1 Non-EDTA treated contaminated soil**

All the plants showed absorption as there was a significant difference (P≤0.05) between the Pb uptake in the plants used for the experiment and their control (plants on non-contaminated, non-treated soil). The uptake of Pb in the control is shown in table 2 while table 3a and b shows the uptake of Pb into the roots and shoots respectively of plants on untreated, contaminated soil. The highest absorption of 81.67±2.35 mg/kg in the roots and corresponding value of 77.35±1.58 in the shoot of *T. triangulare* on 1000ppm contaminated soil was recorded by the second week. These values were significantly higher (P≤0.05) than those recorded for the lower contaminant concentration (Table 3a and b). Obtaining these values by the second week after contamination suggests that *T. triangulare* has gotten to its maximum tolerable limit and the reduction in uptake could arise from the plant adopting a process of detoxification by exudation [1]. *C. odorata* gave the maximum absorption of 103.73±10.2mg/kg in the roots and a corresponding value of 55.68±3.39mg/kg in the shoots by the fourth week. This value however is lower than that reported by Tanhan et al [26] for *C. odorata* on different areas in Bo Ngam lead mine and it could be due to the longer period in which this plant had stayed on this Pb-contaminated soil, the high bioavailability of the metal in the soil and the soil properties. Also, *C. odorata* had a higher uptake into the roots, however the shoot uptake of 55.68±3.39mg/kg which is significantly lower than 77.35±1.58 mg/kg recorded for *T. triangulare* may be an indication of low translocation of the metal from the root to shoot. Of the three plant species studied, *S. nodiflora* gave the highest absorption of 309.52±0.59mg/kg in the root and 127.06±0.30mg/kg in the shoot of plant on 1000ppm contaminated soil by the fourth week.
Furthermore, all the plants showed a direct relationship between Pb-uptake and contaminant concentration and this sequence is similar to that reported by Wang et al [11] for *Bidens maximowicziana* where the highest absorption of 1509.3±98.15 mg/kg in the roots and 2164.7±105.23 mg/kg in the shoots of plant on 2000 ppm contaminated soil were recorded.

### Table 2: concentration (mg/kg) of Pb in control plants

<table>
<thead>
<tr>
<th>Plant</th>
<th>Root</th>
<th>Shoot</th>
<th>TF*</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Talinum triangulare</em></td>
<td>22.14±1.78</td>
<td>16.53±2.14</td>
<td>0.75±0.89</td>
</tr>
<tr>
<td><em>Chromolaena odorata</em></td>
<td>19.42±4.29</td>
<td>11.54±2.37</td>
<td>0.49±0.15</td>
</tr>
<tr>
<td><em>Synedrella nodiflora</em></td>
<td>35.84±2.40</td>
<td>19.88±2.02</td>
<td>0.52±0.55</td>
</tr>
</tbody>
</table>

*TF: Transfer factor*

### Table 3a: Values of Pb absorbed (mg/kg) into the roots of plant on non-EDTA treated contaminated soil

<table>
<thead>
<tr>
<th>Plant</th>
<th>50ppm</th>
<th>100ppm</th>
<th>200ppm</th>
<th>500ppm</th>
<th>1000ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Talinum triangulare</em></td>
<td>19.81±0.28Aa</td>
<td>24.97±7.13Aa</td>
<td>24.75±6.87Aa</td>
<td>34.75±6.70Aa</td>
<td>69.86±0.20Ba</td>
</tr>
<tr>
<td><em>Chromolaena odorata</em></td>
<td>21.87±0.85Aa</td>
<td>25.10±6.38Aa</td>
<td>33.33±0.49Bb</td>
<td>50.10±0.49Cb</td>
<td>52.10±0.49Ca</td>
</tr>
<tr>
<td><em>Synedrella nodiflora</em></td>
<td>25.10±11.78Aa</td>
<td>64.94±11.02Bb</td>
<td>66.67±0.59Bc</td>
<td>145.46±1.22Cc</td>
<td>245.10±6.36Db</td>
</tr>
</tbody>
</table>

* Values with different upper case letters (A-D) along the rows and different lowercase letters (a-c) down the column per week are significantly different from each other using LSD test (P<0.05).

### Table 3b: Values of Pb absorbed (mg/kg) into the shoots of plant on non-EDTA treated contaminated soil

<table>
<thead>
<tr>
<th>Plant</th>
<th>50ppm</th>
<th>100ppm</th>
<th>200ppm</th>
<th>500ppm</th>
<th>1000ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Talinum triangulare</em></td>
<td>14.42±7.54Aa</td>
<td>14.91±7.10Aa</td>
<td>19.67±0.48Aa</td>
<td>24.40±6.89Aa</td>
<td>34.52±3.78Ba</td>
</tr>
<tr>
<td><em>Chromolaena odorata</em></td>
<td>16.67±0.50Aa</td>
<td>25.10±11.78Bb</td>
<td>25.10±11.78Bb</td>
<td>26.67±0.50Bb</td>
<td>30.30±0.55Bb</td>
</tr>
<tr>
<td><em>Synedrella nodiflora</em></td>
<td>18.62±0.62Aa</td>
<td>29.14±12.67Aa</td>
<td>37.23±1.23Bb</td>
<td>55.85±0.49Bb</td>
<td>64.94±11.03Bb</td>
</tr>
</tbody>
</table>

* Values with different upper case letters (A-D) along the rows and different lowercase letters (a-c) down the column per week are significantly different from each other using LSD test (P≤0.05).
3.3.2 EDTA treated contaminated soil

As anticipated from previous studies involving other plants [10, 15, 27] higher absorption of Pb was recorded for plant species on soil treated with EDTA. *T. triangular* had its highest absorption of 88.65±4.28 mg/kg in the root and 64.31±7.50 mg/kg in the shoot of the plant on 500 ppm contaminated soil by the second week. (Table 4a and b). The fact that this absorption was observed at 500 ppm contamination indicates that EDTA had enhanced the bioavailability of the metal when compared to the value of 81.67±2.35 mg/kg which was recorded in the root of the plant on 1000 ppm contamination without EDTA. Furthermore, obtaining this value by the second week corroborates our earlier claim (from the non-EDTA treated soil) that *T. triangular* attained its maximum absorption within two weeks of this study. Similarly, *C. odorata* gave its highest absorption of 165.86±10.2 mg/kg in the root and 74.52±33.99 mg/kg in the shoot of the plant on 500 ppm contaminated soil by the second week. (Table 4a and b). The fact that this absorption was observed at 500 ppm contamination indicates that EDTA had enhanced the bioavailability of the metal when compared to the value of 103.73±10.2 mg/kg in the roots and 55.68±3.39 in the shoot of the plant on 1000 ppm contaminated soil not treated with EDTA. Also, *S. nodiflora* gave a higher absorption of 412.88±36.06 in the root and 129.44±48.37 mg/kg in the shoot of plant on 1000 ppm contaminated soil by the second week. This value, which is the highest of all, indicates that the EDTA had enhanced the bioavailability of the Pb in the soil. Hence *S. nodiflora* was able to attain its highest uptake by the second week and this high absorption was evident in the yellowing of the leaves of this plant indicating its phytotoxicity at this level. The higher uptake or absorption of Pb by the plants on the EDTA-treated soil confirms the report of McBride [12] that one way to induce Pb solubility is by reducing soil pH.

<table>
<thead>
<tr>
<th>Week 1</th>
<th>50ppm</th>
<th>100ppm</th>
<th>200ppm</th>
<th>500ppm</th>
<th>1000ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. triangular</em></td>
<td>10.57±0.78Aa</td>
<td>14.87±7.16Aa</td>
<td>19.72±7.70Aa</td>
<td>39.96±14.22Ba</td>
<td>29.88±0.17Ca</td>
</tr>
<tr>
<td><em>C. odorata</em></td>
<td>33.41±13.66Aa</td>
<td>52.92±19.45Ba</td>
<td>50.20±13.57Bb</td>
<td>63.35±19.27Bb</td>
<td>114.52±31.53Cb</td>
</tr>
<tr>
<td><em>S. nodiflora</em></td>
<td>58.34±11.78Ab</td>
<td>93.08±3.05Ab</td>
<td>108.35±11.79ABc</td>
<td>165.96±22.43Bc</td>
<td>296.97±42.85Cb</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week 2</th>
<th>50ppm</th>
<th>100ppm</th>
<th>200ppm</th>
<th>500ppm</th>
<th>1000ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. triangular</em></td>
<td>37.35±3.52Aa</td>
<td>44.93±7.20Aa</td>
<td>48.57±7.11Aa</td>
<td><strong>88.65±4.29Ba</strong></td>
<td>79.68±8.39Ba</td>
</tr>
<tr>
<td><em>C. odorata</em></td>
<td>56.30±22.37Ab</td>
<td>57.72±27.15Aa</td>
<td>64.90±10.20Aa</td>
<td>70.33±16.98Ba</td>
<td>134.61±40.80Bb</td>
</tr>
<tr>
<td><em>S. nodiflora</em></td>
<td>91.67±11.79Ac</td>
<td>139.40±8.58Ab</td>
<td>200.03±47.09Bb</td>
<td>227.39±15.05Bb</td>
<td><strong>412.88±68.03Cc</strong></td>
</tr>
</tbody>
</table>

* Values with different upper case letters (A-D) along the rows and different lowercase letters (a-c) down the column per week are significantly different from each other using LSD test (P≤0.05).

Table 4a: Values of Pb absorbed (mg/kg) into the roots of plant on EDTA treated contaminated soil

### 3.4 Efficiency for phytoremediation

For the purpose of successful phytoremediation, plants must be able to extract, accumulate and tolerate high levels of heavy metals [28]. The efficiency of these plants for the phytoremediation of Pb will be determined by: Bioaccumulation factor (BF) which is given as ratio of metal concentration in plant shoot to that in soil; and Transfer factor (TF) defined as ratio between concentrations of metals in the shoot to that in the root.
Table 4b: Values of Pb absorbed (mg/kg) into the shoots of plant on EDTA treated contaminated soil

<table>
<thead>
<tr>
<th>Week</th>
<th>50 ppm</th>
<th>100 ppm</th>
<th>200 ppm</th>
<th>500 ppm</th>
<th>1000 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. triangulare</td>
<td>34.32±0.94Aa</td>
<td>29.96±0.51Aa</td>
<td>29.81±0.28Aa</td>
<td>29.82±13.61Aa</td>
<td>34.68±7.54Aa</td>
</tr>
<tr>
<td>C. odorata</td>
<td>25.01±11.79Aa</td>
<td>25.01±11.79Aa</td>
<td>38.34±16.50Ab</td>
<td>25.21±11.78Aa</td>
<td>29.18±5.89Aa</td>
</tr>
<tr>
<td>S. nodiflora</td>
<td>37.23±1.23Aa</td>
<td>37.23±1.23Aa</td>
<td>46.75±14.69Ab</td>
<td>65.37±15.30Bb</td>
<td>100.09±12.74Cb</td>
</tr>
</tbody>
</table>

Week 2
| T. triangulare | 29.38±0.91Aa | 28.28±1.17Aa | 29.17±5.89Aa | 64.91±6.65Bb | 51.48±10.90Bb |
| C. odorata   | 39.85±18.43Ab | 41.77±20.51Ab | 46.71±15.36Ab | 40.87±3.39Aa | 38.47±6.80Aa  |
| S. nodiflora | 39.23±2.25Ab | 46.33±11.63Ab | 64.94±11.03Bc | 64.94±15.92Bb | 129.44±48.36Cc |

Week 3
| T. triangulare | 22.26±3.20Aa | 28.43±1.39Aa | 29.16±7.29Aa | 31.21±2.55Aa | 55.94±18.10Ba |
| C. odorata   | 36.68±18.86Aa | 53.01±4.24Ab | 49.98±23.58Ab | 41.67±11.79Aa | 63.48±26.95Aa  |
| S. nodiflora | 39.23±2.25Aa | 49.37±11.63Ab | 68.94±11.03Bb | 67.34±15.92Bb | 116.92±47.69Cb |

Week 4
| T. triangulare | 40.64±5.90Ba | 23.21±4.54Aa | 42.08±4.14Ba | 41.61±12.11Bb | 43.89±7.30Ba  |
| C. odorata   | 40.13±3.55Aa | 50.11±4.14Ab | 56.54±29.16Ab | 54.37±12.39Aa | 74.52±23.98Bb  |
| S. nodiflora | 37.23±1.23Aa | 54.55±0.49Ab | 72.14±0.83Bb | 72.82±0.52Bb | 92.65±23.26Bb  |

* Values with different upper case letters (A-D) along the rows and different lowercase letters(a-c) down the column per week are significantly different from each other using LSD test(P≤0.05).

Figure 2a: Bioaccumulation factor for plants on untreated soil

Figure 2a shows a plot of the bioaccumulation factor of the plants on untreated soil against the concentration of contaminants. The BF for the plant species was in the order S. nodiflora > C. odorata > T. triangulare. It was observed that S. nodiflora gave the highest bioaccumulation factor ranging from 0.28 - 0.50 and these values were increasing with a corresponding increase in contaminant concentration.

C. odorata gave a bioaccumulation factor ranging from 0.20 - 0.39 while T. triangulare gave the least value ranging from 0.17 - 0.27.

Plants on EDTA treated soil gave a higher BF (fig 2b) compared to those on untreated, contaminated soil. This may be as a result of the increased bioavailability of Pb in the soil solution which will be available for plant uptake. The values of 0.22 - 0.28, 0.28 - 0.43 and 0.33
- 0.61 were recorded for *T. triangulare*, *C. odorata* and *S. nodiflora* respectively in the same order as those on untreated soil above.

![Fig 2b: Bioaccumulation factor for plants on EDTA-treated soil](image)

![Fig 3a: Transfer factor of plants on untreated soil.](image)

The Transfer factor (TF) is equally an important parameter in accessing the ability of a plant for successful phytoremediation. It measures the efficiency of a plant in translocating metals from root to overground parts which is a very important process in phytoremediation. One of the indicators that define a Pb hyperaccumulator is that the TF or shoot:root ratio \( \div 1 \) [8]. A higher TF is important in practical phytoremediation of heavy metal contaminated soil because it enables phytoremediation by harvesting only the above-ground parts of the plants [29]. However, the plants used in this study showed a poor translocation of Pb from root to shoot as majority of
the plants gave TF less than 1(Fig 3a and b). This constitutes another constraint to the phytoremediation of Pb by these plants.

The transfer factors observed in these plants are in the order: *T. triangulare* □ *C. odorata* □ *S. nodiflora*. The highest uptake of Pb into the plant parts was observed in *S. nodiflora*, however, it exhibited the lowest transfer factor, both for treated and untreated soil, which constitute a major set-back to its use as a potential phytoremediator of Pb since the success of phytoremediation depends on harvesting the above-ground parts. *T. triangulare* which showed the lowest uptake of Pb out of the three plant species, however, gave the highest transfer factors both for treated and untreated soil which could have been an added advantage to its phytoremediation ability except for its low uptake of Pb. Furthermore, *C. odorata* gave transfer factors that falls within the range for the other two plant species.

A plant that will be classified as a Pb hyperaccumulator should meet the following conditions: (1) the concentration of Pb in plant shoots □ 1000mg/kg [8]; (2) the concentration of Pb in shoots is 10-500 times more than Pb in plants from non-polluted area (control) [30]; (3) the TF or shoot:root ratio □ 1 [8,31]. The plants investigated in this study, however did not successfully meet these requirements and they may not be classified as a hyperaccumulator of Pb.

**CONCLUSION**

The plant species used in this experiment showed a significantly higher absorption of Lead compared to their individual control. It could also be observed that treatment of the soil with EDTA enhanced the uptake of Pb in the plants by increasing the bioavailability of Pb in soil solution. The uptake of Pb observed in these plants are in the order *S. nodiflora* □ *C. odorata* □ *T. triangulare* both in the roots and shoots and this order holds both for treated and untreated soil.
In the light of this study, *S. nodiflora* has shown the potential to be useful for phytoremediation of Pb-contaminated soil as it gave a significantly higher absorption of Pb even on soil not amended with EDTA despite the challenges of Pb phytoremediation. According to Baker and Brooks [8], hyperaccumulators are metal specific and are adapted to precise climate and soil conditions. Hence, these plants could also be investigated for the phytoremediation of other heavy metals. Furthermore, more research work should be done to explore the phytoremediation potential of *S. nodiflora*.

REFERENCES


